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THE EFFECT OF SPECIFIC INTENSITIES AND MODES OF TRAINING ON MAXIMUM OXYGEN CONSUMPTION

by

© David J. Smith

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

FALL, 1978

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled THE EFFECT OF SPECIFIC INTENSITIES AND MODES OF TRAINING ON MAXIMUM OXYGEN CONSUMPTION submitted by David J. Smith in partial fulfilment of the requirements for the degree of Master of Science.

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Date.....6th June 1978.....

ABSTRACT

The purpose of this research was to investigate the relative effect of continuous and interval modes of training and two different relative intensities (training heart rates of 140 and 172 b/min.) on a commonly used indicator of endurance fitness ($\dot{V}O_2max$).

Twenty-four subjects were randomly assigned to one of four groups: continuous 140 b/min, continuous 172 b/min, interval 140 b/min. and interval 172+ b/min. Each group was divided into low and high fitness categories (low fitness < 51 ml/kg/min. < high fitness), the total work of each category being 16,500 and 19,500 kpm respectively. Following 10 training days, each group then exercised at a common relative intensity of 160 b/min. for a further 10 sessions.

After the first section of training, there was an increase ($p<0.01$) in $\dot{V}O_2max$ for the 172 b/min. versus 140 b/min. relative intensity training groups, and the $\dot{V}O_2max$ for continuous training was higher ($p<0.01$) than that of interval training. Statistical analysis showed that the $\dot{V}O_2max$ achieved with continuous training at 172 b/min. was higher ($p < 0.01$) than all other pre and mid-test values. The average $\dot{V}O_2max$ of the continuous 172 b/min. group increased by 15.1% (49.4 to to 56.9 ml/kg/min.) in 10 training sessions. The high intensity interval training showed no statistically significant change in $\dot{V}O_2max$ as compared to pre-training values.

It is suggested that by using heart rate as an indicator of relative intensity, the stimulus at each training session will be very similar, allowing for adaptations that may take place at both the systemic and peripheral level. Thus, by continuous training at a high relative intensity rapid changes may be elicited in $\dot{V}O_2max$.

ACKNOWLEDGEMENTS

I wish to thank my committee members, Dr. A. Quinney and Dr. M. Smith and also Professor T. Wall for his help with the statistics.

Special thanks are owed to my advisor and Chairman, Dr. H.A. Wenger, for his advice in the writing of this thesis.

Thanks go to all the subjects who volunteered their time and effort at some time during the nine months of data collection, and to Sue Vickovic for typing this manuscript.

PREFACE

This research began in 1974 and would not have started without the help of Dr. P.R. Travers (St. Luke's College, Exeter, England), and my friends at St. Luke's, John Adams, Dave Clarke, Steve Collier, Pete Hawkey, Roger Randall, Charlie Slather and Dick Telford.

The initial idea of a quantified training system (QTS) was developed in March, 1974 and as a result of relentless training on a treadmill by my colleagues from January to March, 1975, the primary concepts of the system were developed.

The objective of this research is the quantification of training in order to allow athletes to train in such a way that the specific effects of their training and their potential can be accurately assessed.

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INTRODUCTION

An assessment of the relative fitness levels of athletes coupled with knowledge of specific training methods, is of extreme importance to coaches in all aspects of sport. Although many years have been spent in examining the various physiological responses to different training methods, it is still apparent that the exercise physiologist has difficulty in assessing relative fitness. As well, the principle difficulty encountered in finding a blueprint for training is that in analysing the wide variety of methods used, there does not appear to be one universally accepted method.

Maximal oxygen uptake ($\dot{V}O_2max$) is one of the most commonly used dependent variables, a variable which measures the combined ability of the body to take up, transport and utilize oxygen.

The $\dot{V}O_2max$ of athletes has been the focal point of research for decades, and is a well established indicator of an individual's ability to perform sustained heavy muscular exercise. It has also been used as a measure of cardio-respiratory performance as well as a predictor of endurance performance.

Values for five international runners were reported by Robinson et al. (1937), whose results exceeded previously recorded values. Astrand (1955) published data on $\dot{V}O_2max$ with a highest value of 5.88 l/min (81.7 ml/kg/min), and since then other studies have reported even higher levels (Saltin and Astrand, 1967; Costill et al. 1976), the highest value being 94 ml/kg/min by a Finnish skier (Astrand, 1973).

As a predictor of endurance performance, correlation coefficients of 0.91 (Costill,1973) and 0.84 (Shephard, 1973) have been reported for distance running and endurance swimming respectively.

Shephard (1969) suggests two possible reasons as to why $\dot{V}O_2max$ is singled out as the best single measure of cardio-respiratory performance: (1) it is the dominant physiological factor in most activities lasting from 1 to 60 min, and (2) activities of this duration are of prime importance to the average person.

Another area in which $\dot{V}O_2max$ has been utilized is the area of physiological adaptations to exercise programmes. It is the most widely used dependent variable in assessing magnitude of 'training effect' (Orlander et al.1977; Eddy et al.1977; Kiessling et al.1974; and Saltin et al.1969) and with endurance performance in athletics (Fox et al.1977; Fox et al.1973).

The most frequently studied training independent variables which influence the optimal achievement of the training effect are exercise intensity, duration, frequency and initial level of fitness (Fox et al. 1977, and 1975; Wenger and Macnab,1975; Fox et al.1973; Davies and Knibbs 1971; Sharkey,1970; Faria, 1970; Shephard, 1968; Roskamm, 1967; Sharkey and Holleman, 1967; and Karvonen et al.1957).

Many studies have investigated these factors in a systematic way, but it is possible that their conclusions may be somewhat erroneous due to the lack of control of total work performed. Exercise intensity is regarded as the most important factor by most authors in achieving a training effect. But, the increase in intensity usually corresponded with an increase in total work (Fox et al, 1973; Davies & Knibbs, 1971,

Faria, 1970; Shephard, 1968; Sharkey and Holleman, 1967). Some studies however, have controlled total work when assessing such variables as intensity, training threshold and duration (Fox et al, 1977; Eddy et al.1977; Burke and Franks, 1975; Wenger and Macnab, 1975; Sharkey, 1970). Investigations dealing with frequency and duration may have confounded their conclusions for the above reasons, although it is generally accepted that more frequent exposure to a training stimulus produces greater training effects. (Pollock et al 1969; Shephard, 1968).

Many questions regarding the relative effectiveness of continuous versus interval training programmes still remain unanswered. Some authors (Eddy et al.1977; Edwards et al.1973; Fox et al.1969; Roskamm, 1967) have attempted to compare the effect of continuous versus interval modes of training on endurance performance, as measured by VO_2max, whereas others (Fox et al.1977, Knuttgen et al.1973; Fox et al.1973) have only studied interval training.

The conventional method of regulating training intensity involves training at intensities relative to VO_2max (Hickson et al.1977; Orlander et al.1977; Gollnick et al.1973; Davies and Knibbs, 1971), but some investigators have used heart rate as a measurement of relative overload such as Burke and Franks (1975) who used percentage maximum heart rate. Some researchers have used specific heart rates directly (Sharkey, 1970; Sharkey and Holleman, 1967), while other have used ranges of heart rate, e.g. 140-150 b/min. (Massicote and Macnab, 1974; Faria, 1970). Sharkey and Holleman (1967) comment:

> A fundamental determinant of exercise intensity would seem to be one or several physiological criteria reflecting the actual involvement of the

organism during exercise. Exercise heart rate would seem to be a useful indicator of 'cardiac' involvement during exertion.

From this discussion there is conflicting evidence in the measurement of physiological adaptations to endurance training as to whether it is the mode of training (interval versus continuous), intensity, duration or total work performed which is the primary stimulus to the training effect.

It is the purpose of this study to investigate the relative effect of two different modes of training (continuous and interval) and two different relative intensities (training heart rates of 140 and 172 b/min) on a commonly used indicator of endurance or cardio-respiratory fitness ($\dot{V}O_2$max ml/kg/min).

Definition of Terms

Maximal oxygen uptake: refers to maximal volume of oxygen which can be consumed per minute (litre/min. or ml/kg/min.).

Endurance performance: refers to any prolonged work that requires a regular supply of oxygen and substrates for its completion.

Continuous training: refers to an uninterrupted power output over a prolonged period of time.

Interval training: refers to a series of repeated bouts of exercise alternated with periods of rest.

Exercise time: refers to the time of the exercise bout.

Start time: refers to the time taken to increase the heart rate by 10 beats/min. from a given recovery heart rate.

Recovery heart rate: refers to a given level to which the heart rate is allowed to recover to during the rest period.

Power output: refers to performance of work expressed per unit of time (e.g. kpm/min.).

Low fitness group: refers to those subjects whose $\dot{V}O_2$max is below 51 ml/kg/min.

High fitness group: refers to those subjects whose $\dot{V}O_2$max is above 51 ml/kg/min.

Training series: refers to the 5 week training period.

Training section: refers to the 10 training days.

Training session: refers to 1 training day.

METHODOLOGY

Subjects

The subjects were 24 university students at the University of Alberta who volunteered to participate in the study. The majority of the subjects were physical education students. They ranged in age from 19 to 32 years ($\bar{X}$ = 22.91 yrs, SE = 0.64 yrs) and in weight from 61.22 to 82.08 ($\bar{X}$ = 73.71 kg, SE = 1.23 kg). During the study the subjects were asked to refrain from any systematic or vigorous physical activity other than that associated with the experiment.

Testing Sessions

All subjects were given a pre, mid and post training evaluation test. All testing and training was performed on a Monark stationary bicycle ergometer which was calibrated and checked before each training series. The saddle height was adjusted in such a manner that the subject's legs would be slightly flexed at the lowest point of the revolution. The pedal frequency was set at 60 rpm for tests and training in accordance with the findings of Hermansen and Saltin (1969).

Testing Procedure

At each test, the body weight was measured with the subject clad only in gym shorts. After ECG and Cardiometer leads had been attached

to the subject, he performed submaximal work for 5 minutes, at a power output which elicited a heart rate of approximately 140 b/min, the power output having been ascertained during an orientation (p. 11) Heart rate was continuously monitored on the cardiometer, and during the last minute of exercise, an ECG trace and an oxygen uptake were recorded.

After a 5 minute rest, the subject then performed a pre-max warm up for 2½ minutes at a power output that would elicit a heart rate of approximately 160 b/min.

Following a 30 second rest, the subject worked until $\dot{V}O_2$max had been reached. The criterion that $\dot{V}O_2$max had been reached was a levelling off of $\dot{V}O_2$; less than 150 ml/min increase over the previous power load. (Taylor et al. 1955). The normal work time was 3 minutes above a heart rate of 160 b/min. During the maximal exercise period, oxygen uptake was monitored every 30 seconds and an ECG trace was recorded from 2 minutes to the end of exercise.

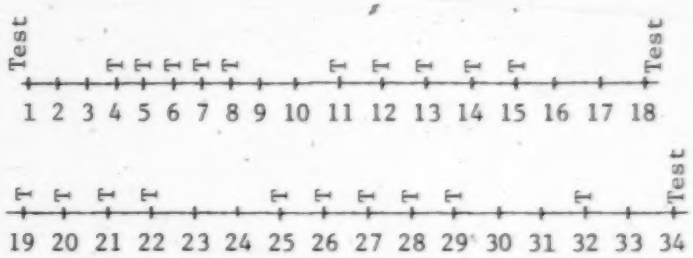
Apparatus

During all gas collection periods, the subject was fitted with a nose clip, a rubber mouth piece and a Rudolph valve. The expired air was analyzed automatically by a Metabolic Measurement Cart, Beckman Instruments Inc., Illinois, which was calibrated before each test. Electrocardiographs were recorded by a Sandborn 500 Viso-Cardiette, and in order to allow the investigator to monitor heart rate directly, a Cardiometer (Cardionics ab, Stockholm, Sweden) was used. The latter

instrument was also used for monitoring training heart rates and was calibrated using an osilliscope prior to each training series.

Testing and Training Sequence

The training was divided into two sections, each section consisting of 10 training days, training taking place 5 days per week. Pre, mid and post training tests were performed by all subjects, before, between and after the two training sections. The training tests, where $\dot{V}O_2max$ was determined, were administered at least one day after the end of each training section.



Time In Days

Figure 1. Schematic Diagram of Testing and Training Format.

The mode of training was divided into continuous and interval training. During the first training section, the intensity was divided within each mode, but during the second section, the intensity for all groups was the same. High and low fitness groups within each intensity performed different total work, the fitness group being determined by initial $\dot{V}O_2max$ values (low fitness < 51 ml/kg/min < high fitness).

The intensity for the first training section was divided into power outputs corresponding to 140 b/min. and 172 b/min. whereas during the second section the heart rate criterion was 160 b/min. for all groups.

The total work per training session for the low fitness group was 16500 kpm ± 500 kpm for continuous training and ± 1000 kpm for interval training. For the high group the total work was 19,500 kpm, with the same variations for training mode as with the low group.

The continuous training group exercised at the specified intensities as determined by heart rate which was continuously monitored by a cardiometer. The variation of the heart rate was held within ± 2 b/min. and the load was adjusted accordingly until the accumulated work reached the specified total.

The interval training intensities of 140, 160 and 172+ b/min. had varying exercise, recovery and starting times. The workout for the interval 172+ b/min. group (I172) consisted of 30 seconds work after the heart rate had reached 160 b/min, alternated with relief intervals long enough to allow the heart rate to return to 150 b/min. The work accumulated at each repetition was the sum of start time - time taken to increase the heart rate from 150 b/min. to 160 b/min., plus 30 seconds (exercise time). The intensity averaged 127% of $\dot{V}O_2$max for the first half of the total number of repetitions (± 1 rep.), and 117% for the second half. The total work was, as previously specified for each fitness group, ± 1000 kpm since no half repetitions were performed.

MODE	CONTINUOUS				INTERVAL			
INTENSITY	140		160		172		160	
TESTS	Pre	Mid	Post		Pre	Mid	Post	
SUBJECTS	1				1			
	2				2			
	3				3			
	4				4			
	5				5			
	6				6			

MODE	INTERVAL			
INTENSITY	140		160	
TESTS	Pre	Mid	Post	
SUBJECTS	1			
	2			
	3			
	4			
	5			
	6			

MODE	INTERVAL			
INTENSITY	172+		160	
TESTS	Pre	Mid	Post	
SUBJECTS	1			
	2			
	3			
	4			
	5			
	6			

Figure 2. Schematic Diagram of Experimental Design.

The interval 160 group (I160) exercised for 90 seconds above a heart rate of 145 b/min, with a maximum heart rate of 160 b/min, alternated with relief intervals long enough to allow the heart rate to return to 135 b/min. The accumulated work was the sum of the start time time taken to increase the heart rate from 135 b/min to 145 b/min, plus 90 seconds. The work was adjusted to elicit a heart rate of 160 ± 2 b/min. for the last 60 seconds of each repetition.

The interval 140 group (I140) exercised for 3 minutes above a heart rate of 130 b/min. with a maximum heart rate of 140 b/min., alternated with relief intervals long enough to allow the heart rate to return to 120 b/min. The accumulated work was the sum of the start time - time taken to increase the heart rate from 120 b/min. to 130 b/min., plus 3 minutes. Again the work was adjusted to elicit a heart rate of 140 ± 2 b/min. for the last 2 minutes.

Table 1. Summary of Interval Training Format

Intensity	Exercise Time	Starting HR at	Recovery HR at
172+ b/min.	30 secs.	160 b/min.	150 b/min.
160 b/min.	90 secs.	145 b/min.	135 b/min.
140 b/min.	3 min.	130 b/min.	120 b/min.

As can be seen in Table 1, the exercise time increased with a corresponding drop in training intensity. The starting heart rate decreased also from 12 to 15 b/min. for 172 and 160 b/min. to 10 b/min. for 140 b/min. training intensity. The recovery heart rate was kept constant at 10 b/min. below the starting heart rate.

Pre-Test Orientation

The subjects reported to the laboratory during the week prior to the pre-test on an average of three occasions. At these times they were familiarized with both the training procedure and testing equipment. Power outputs at given heart rates were recorded to be used in the pre-training test.

Randomization

Following the pre-training test, the subjects were classified into low or high fitness categories and then randomly assigned to one of the four types of training.

(a)	Continuous 140 b/min.	(c)	Interval 140 b/min.
(b)	Continuous 172 b/min.	(d)	Interval 172+ b/min.

Statistical Analysis

The statistical analysis of the results involved a three-way analysis of variance with repeated measures. The statistical computations were made using an ANOV30 (DERS programme). Post hoc procedures involved

a Newman-Keuls test for locating significant mean differences as well as simple effects testing followed by appropriate t-tests. Significant differences were accepted at the alpha level p is less than 0.05 where p is the probability that no difference exists between the means.

RESULTS

No statistical difference ($p > 0.05$) was shown to exist on the pre-training $\dot{V}O_2max$ between any training mode or intensity group.

After the first section of training there was an overall increase ($p < 0.01$) in $\dot{V}O_2max$ from the pre-training value (Figure 1). After the second section however, there was still a significant elevation ($p < 0.05$) as compared to the pre-training value, but no statistical difference was shown between mid and post tests.

When the two modes of training (interval and continuous) were pooled, the mid-test showed an increase ($p < 0.01$) in $\dot{V}O_2max$ for the 172 b/min. versus 140 b/min. relative intensity training groups. (Figure 2). Furthermore, compared to pre-training test values, the 172 b/min. group showed an increase ($p < 0.01$) whereas the 140 b/min. groups showed no statistical improvement. Following the second section of training at a common relative intensity (160 b/min.), the mid-test statistical difference between the two groups had been eliminated.

Following the first training section, with the two relative intensities pooled (i.e. 140 and 172 b/min.), the analysis showed that the $\dot{V}O_2max$ for the continuous training was higher ($p < 0.01$) than that of the interval training. However, following the common intensity (160 b/min.), this statistical difference between the two modes of training was no longer apparent (Figure 3).

Statistical analysis between the means of a matrix composed of training modes, intensities and test times, showed that the $\dot{V}O_2max$

achieved with continuous training at 172 b/min. was higher ($p < 0.01$) than all other pre and mid-test values (Figure 4). The average $\dot{V}O_2max$ of the continuous 172 b/min. group (C172) increased by 15.1% (7.34 ml/kg/min) in 10 training sessions; the largest increase in one subject being 27.1% (12.46 ml/kg/min). The high intensity interval training showed no statistically significant change in $\dot{V}O_2max$ as compared to pre-training values. Following a decrease from 172 b/min. to 160 b/min. in relative training intensity, the $\dot{V}O_2max$ decreased by 1.9 ml/kg/min. for both continuous and interval modes, and therefore the previous statistical difference between the two modes was still maintained ($p < 0.01$).

No difference was seen between continuous and interval modes at 140 b/min. when comparing pre and mid-test $\dot{V}O_2max$ values. No statistical difference in $\dot{V}O_2max$ was elicted in the two groups when exposed to the common training intensity of 160 b/min.

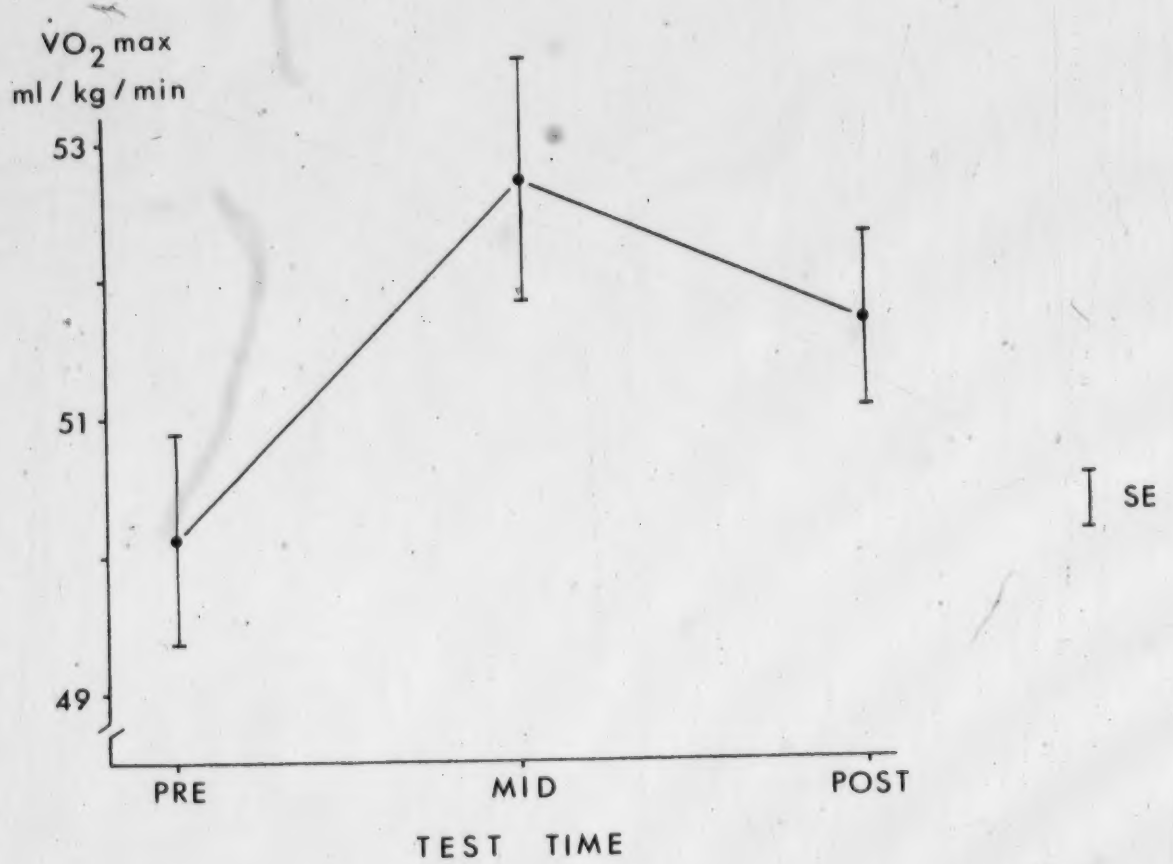


Figure 1. The Effect of Training on $\dot{V}O_2$max.

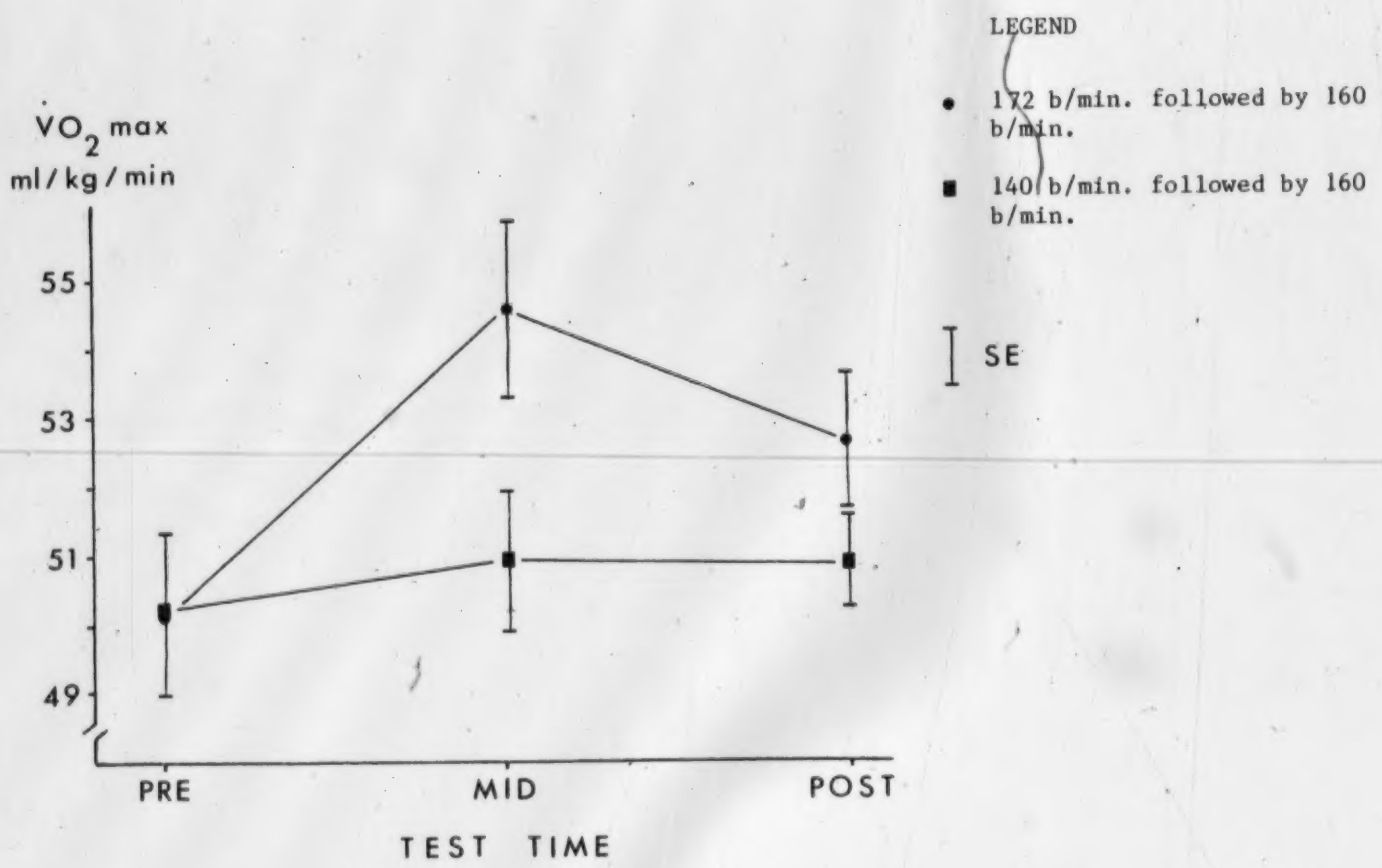


Figure 2. The Effect of Training at Relative Intensities of 140 and 160 b/min., and 172 and 160 b/min. on $\dot{V}O_2$max.

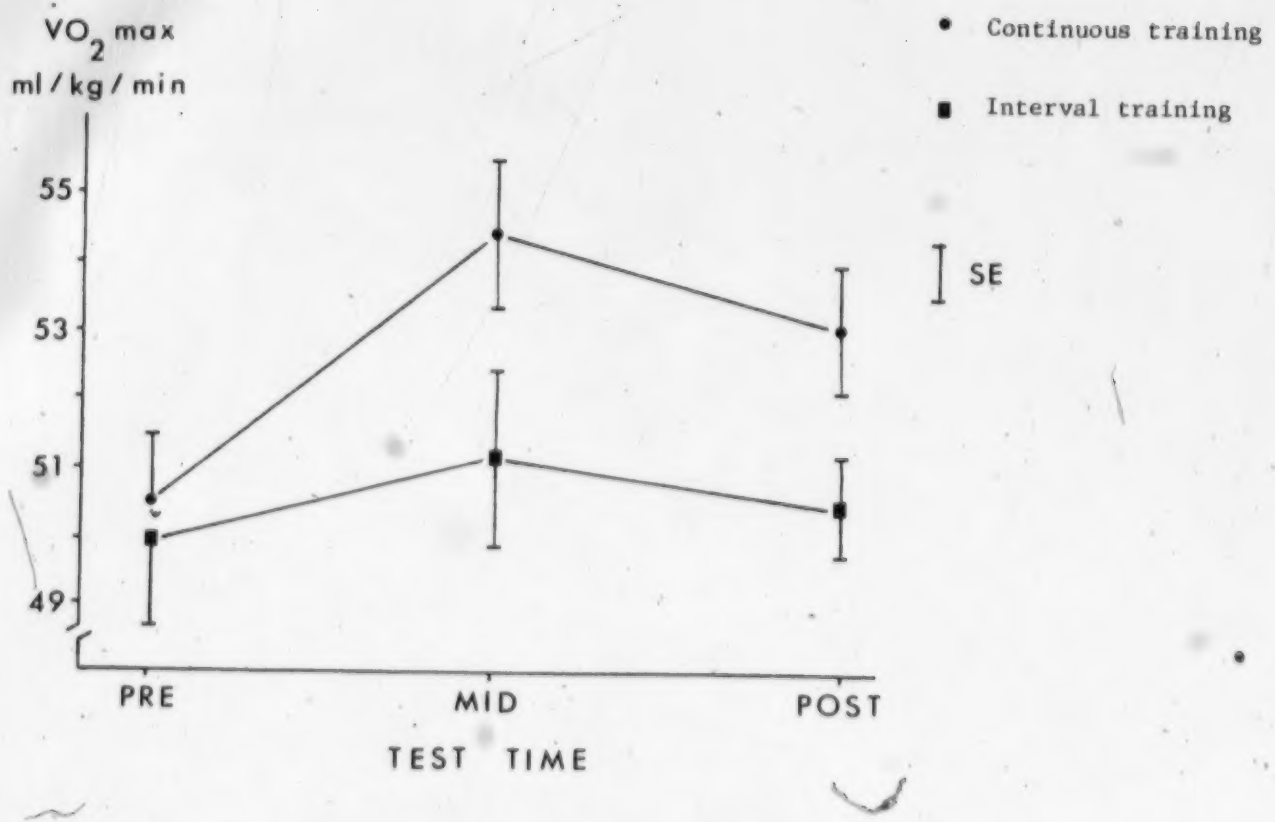


Figure 3. The Effect of Continuous and Interval Training on $\dot{V}O_2$max.

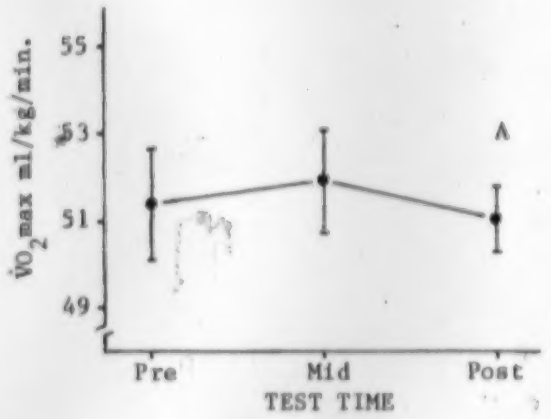


Fig. 4.1

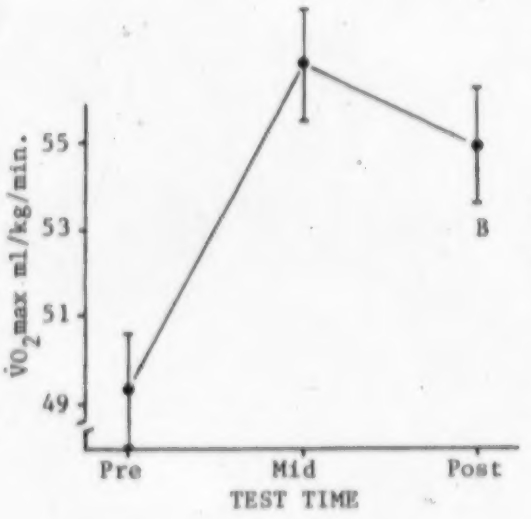


Fig. 4.2

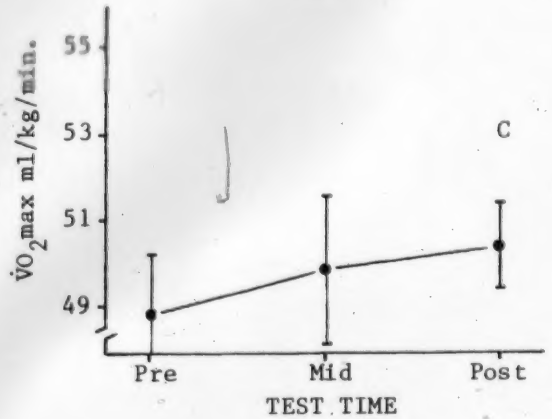


Fig. 4.3

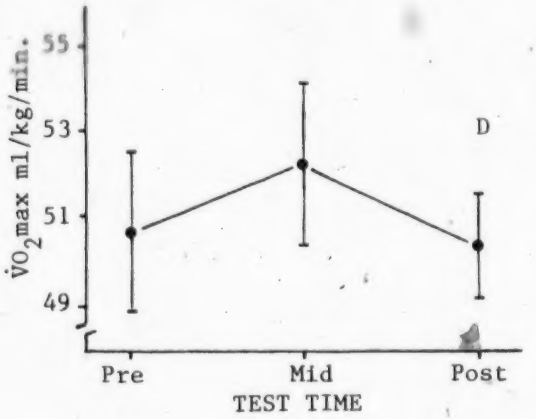


Fig. 4.4

LEGEND

A C140 and C160 b/min.

B C172 and C160 b/min.

C I140 and I160 b/min.

D I172+ and I160 b/min.

SE

Figure 4.1 - 4.4. The Effect of Specific Training on $\dot{V}O_2$max.

DISCUSSION

The mean increase (15.5%) in $\dot{V}O_2$max as a result of 10 days of continuous training at 172 b/min. is within the range of 5-20%, reported for increases in $\dot{V}O_2$max in a number of training studies (Eddy et al. 1977; Fox et al. 1977; Knuttgen et al. 1973; Ekblom et al. 1968; Sharkey and Holleman, 1967). The largest increase has been reported in postcoronary patients training for a marathon, where the increase was approximately 57% (29 to 45.6 ml/kg/min.) (Kavanagh et al. 1974). Saltin et al. (1968) reported an increase of 31, 52 and 31% in three previously sedentary subjects and 2 and 8% increases in trained subjects as a result of 55 days of mixed interval and continuous exercise. In the present study, increases of 15-27% over 10 training days were achieved in 4 subjects whose mean pre-training $\dot{V}O_2$max was 47.6± 1.4 ml/kg/min. The two other subjects in the C172 group only improved 4.8 and 5.7%. The largest previously reported increase over a two week period was 27.9% reported by Hickson et al. (1977), in a subject whose pre-training $\dot{V}O_2$max was 26.7 ml/kg/min. Their next highest reported improvement was 12.5% for a subject whose pre-training $\dot{V}O_2$max was 45.4 ml/kg/min. This is comparable with the pre-training values of the subjects in the present study. However, Hickson et al. used training overloads consisting of continuous running as fast as possible for approximately 35 minutes, 3 days/week, alternated with interval training on the other days. The interval training consisted of six 5 minute-long intervals of bicycling against a resistance adjusted

so that each subject attained $\dot{V}O_2$max during the 5 minute exercise period. During 2 minutes of recovery, subjects pedalled at 50-60% $\dot{V}O_2$max. As can be seen from the above methods, Hickson et al. used both interval and continuous modes at a high intensity to produce changes in $\dot{V}O_2$max. However, the results from the present study indicate that continuous training at 172 b/min. can improve $\dot{V}O_2$max as fast in only 10 training days.

It is difficult to compare the magnitude of these changes in $\dot{V}O_2$max with other studies because of their lack of quantification of training in terms of mode, intensity, initial fitness levels, frequency and duration of sessions, and total work. In this study however, a comparison between high intensity continuous and interval modes indicates that the continuous mode produces greater improvement ($p < 0.01$) in $\dot{V}O_2$max than the interval mode over 10 training days. Over the 10 training days, the high intensity interval mode also failed to produce a significantly greater improvement in $\dot{V}O_2$max than that produced by interval training at a relative intensity of 140 b/min.

Training at a relative intensity of 140 b/min. did not increase $\dot{V}O_2$max in either mode and increasing the intensity to 160 b/min. for a further 10 training days also failed to demonstrate any significant difference between modes on $\dot{V}O_2$max. A common relative intensity of 160 b/min. for 10 training days following the high intensity (172 b/min) training, showed no difference between the two modes of training. It is possible that since the 160 b/min. relative intensity is close to the previous load (172 b/min.), that the $\dot{V}O_2$max changes were maintained over the 10 training day period. However, although the $\dot{V}O_2$max following

160 b/min. training was not statistically different from the $\dot{V}O_2max$ following 172 b/min. training, the values were 1.9 ml/kg/min. lower. This may suggest that if the 160 b/min. training was extended over a longer period, the expected depression in $\dot{V}O_2max$ as a result of a lowered relative intensity, would occur.

Fox et al.(1977) compared two types of interval training, short duration high power and long duration lower power. The exercise for the short duration group consisted of a maximum of 19 runs of 30 seconds duration alternated with relief intervals allowing the heart rate to return to 120-140 b/bmin. The long duration group exercise consisted of 7 runs of 2 minutes duration with relief intervals the same as the short duration group. The exercise heart rate in both groups averaged 175-180 b/min., and the two programmes were equated on the basis of total distance covered per training session. Although both groups showed significant increases in $\dot{V}O_2max$ after 8 weeks of 3 days per week training, the larger mean increase in $\dot{V}O_2max$ (ml/kg/min) was found in the longer duration group, as compared to the short duration group (8% vs. 4.5% respectively).

Although his training methods were different from Fox et al, Roskamm (1967) also indicated that long exercise periods (2½ mins) were equally or more effective than a one minute high intensity exercise interval. Knuttgen et al.(1973) also found that 3 minute exercise periods were more effective than 15 second periods. This seems to indicate that for interval training to elicit optimal improvements in endurance performance as measured by $\dot{V}O_2max$, the intensity must be

above 170 b/min., and the work interval should be of a long duration.

Fox et al.(1977) reported that over the entire training session in their study, the average $\dot{V}O_2$ was 66% for the short duration group and for the long duration group, 70% during minute 0-1, and 96% during minute 1-2. Eddy et al.(1977) found that interval training resulted in the same response as continuous training in the improvement of $\dot{V}O_2$max. In this study, the interval group trained at 100% $\dot{V}O_2$max with a work: rest ratio of 1:1 (1 minute work, 1 minute rest), and the continuous group exercised at 70% $\dot{V}O_2$max, the total daily work output being equated It is therefore possible from the findings of Fox et al.(1977), that the interval group trained by Eddy et al.were not loading the oxygen transport system to 100% $\dot{V}O_2$max but were nearer 70%, the relative intensity at which the continuous group were training. Consequently, Eddy et al. found similar improvements in $\dot{V}O_2$max with both modes of training.

It may be suggested therefore that the oxygen transport system is being loaded at a high percentage of $\dot{V}O_2$max in continuous 172 b/min. training for a long enough period of time that makes this form of training most effective. Wenger and Macnab (1975) also suggested that the significantly greater improvements in $\dot{V}O_2$max displayed by training at 100% $\dot{V}O_2$max as opposed to 60% $\dot{V}O_2$max, implied that the intensity of training which taxes the oxygen transport system to its fullest is the main factor in improving endurance fitness as measured by $\dot{V}O_2$max. Sharkey (1970) however, failed to show any significant improvement in a group that trained continuously at 170 b/min., probably because of the methods he used in testing endurance performance. The tests used were an Astrand-Ryhming step test prediction of $\dot{V}O_2$max, a Balke treadmill

test (T_{170}) and a Sjostrand physical working capacity test (PWC_{170}).

It may be suggested that an advantage of using heart rate as an indicator of relative intensity is the fact that since the transport and utilization of oxygen are linked, changes occurring at the tissue level or at the systemic level, are mirrored by changes in the function of the heart. It is well documented that one of the most pronounced and consistant changes associated with endurance training is a decreased heart rate during submaximal exercise following training (Orlander et al.1977; Fox et al.1975; Wenger and Macnab, 1975; Knuttgen et al.1973; Fox et al.1973; Ekblom et al.1968; Frick et al.1967). This change may be caused by an increase in stroke volume (Ekblom et al.1968; Saltin et al.1968) changes in muscle blood flow (Grimby et al.1967; Varnauskas et al.1970), or changes in oxidative metabolic potential (Henriksson and Reitman, 1977) or any combination of these.

Davies et al.(1970) reported that during the first three occasions of submaximal work, at a given power output, the circulatory system showed evidence of a profound change. The heart rate at a given $\dot{V}O_2$ of 1.5 l/min. decreased from a mean value of 145 b/min. on day 1 to 124 b/min. on day 7. Similar changes were observed in the present study with increasing power outputs for a given heart rate (Appendix C.). Davies et al.(1970) suggest that a larger than normal volume of blood was used for a given oxygen uptake.

As a consequence of using heart rate as an indicator of relative intensity, the stimulus or relative overload under which the body is placed at each training session will be very similar allowing for adaptations that may take place at both the systemic and peripheral level.

The procedure of training humans at specific percentages of $\dot{V}O_2max$ has been used extensively to attempt to control the relative overload. Because of the complexity of the $\dot{V}O_2max$ test, the procedure does not usually allow for adaptations that may take place during the training programme. Thus an initial overload of 70% $\dot{V}O_2max$ may be reduced to 50% or less in terms of relative overload during the space of a short period of exposure to the training stimulus. The rapid response in this study to continuous training at 172 b/min. may thus be explained by the fact that the subjects were exposed to a very similar relative overload from day to day. However, the varying response of the subjects to the training, in terms of change in $\dot{V}O_2max$ (4.8% to 27.1%) brings into the question the use of $\dot{V}O_2max$ as an indicator of the effectiveness of oxygen transport and utilization.

Ekblom (1969) reported several cases of the ceiling effect of maximum aerobic capacity where individuals had trained for many years improving performance, but showing little or no change in $\dot{V}O_2max$. Orlander et al. (1977) however, have recently suggested a separation of systemic and local training effects. It appears possible to increase muscle metabolic capacity without a change in $\dot{V}O_2max$. Furthermore, their observations indicate no causal relationship seems to exist between $\dot{V}O_2max$ and muscle metabolic capacity in sedentary or moderately trained men.

Faulkner (1968) comments that world athletes over the past 30 years may well have reached man's capacity for aerobic work considering that approximately 30 years ago, Dill et al. (1967) observed $\dot{V}O_2max$ values of 80.0 ml/kg/min. for trained athletes. Very similar values have been

reported by Costill et al. (1976) for elite distance runners of the present time. Since little change has been shown to exist in apparent endurance fitness levels of athletes, perhaps it is the inability of exercise physiologists to show the changes that must have occurred as performance times have improved dramatically. It appears therefore that future research should consider more discriminating techniques for the assessment of relative endurance fitness.

CONCLUSIONS

From this study the following conclusions can be outlined:

1. There is no difference in $\dot{V}O_2max$ by training in either the continuous or interval mode at relative intensities of 140 b/min. or 160 b/min. for 10 training sessions.

2. High intensity interval training shows no statistically significant change in $\dot{V}O_2max$ in 10 training days as compared to pre-training values.

3. Training in the continuous mode at a relative intensity of 172 b/min. results in a significant increase in $\dot{V}O_2max$ in 10 training days.

RECOMMENDATIONS

1. Caution should be exercised when interpreting the fact that continuous 172 b/min. produces an increased $\dot{V}O_2max$ in a short period of time. The long term effects and the effects of training at low intensities may be hidden by the use of a gross variable, $\dot{V}O_2max$, in assessing 'training effect'.

2. There is a need for further research in developing techniques for assessing specific systemic and peripheral changes that occur through training without using invasive methods.

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APPENDIX A

APPENDIX A

REVIEW OF LITERATURE

As there are many aspects of endurance training, this review is presented under the following headings: quantification of training, intensity, mode of training, studies comparing continuous and interval training, and finally, mechanical efficiency.

Quantification of Training

Sharkey and Holleman (1967) comment that one aim of exercise physiology would be a quantification of the specifics of endurance. However, in order to adequately quantify endurance training and its physiological effects, evaluation criteria must be clearly set out so that critical examination may be undertaken.

On reviewing the literature, cardiovascular fitness is evaluated by a wide variety of physiological variables, with the result that there is a problem of interpreting and comparing research studies particularly when investigators neglect to quantify training procedures. Physiological variables utilized by investigators in the evaluation of training effects include changes in maximal oxygen uptake (max $\dot{V}O_2$) (Hickson et al. 1977; Fox et al. 1975) cardiac output (Ekblom et al. 1968; Saltin et al. 1968), lactic acid (Fox et al. 1975; Karlsson et al. 1972; Ekblom et al. 1968)

stroke volume (Frick et al.1963; Saltin et al.1968) and heart rate (Fox et al.1973; Fox et al.1975; Ekblom et al.1968), the variables being measured at maximum and at given submaximal power outputs.

$\dot{V}O_2$max is the most commonly used dependent variable in evaluating conditioning results. Table 2 shows improvement in $\dot{V}O_2$max from conditioning investigations.

Although not used extensively, oxygen pulse has been used by some researchers (Ekblom et al.1968; Wilmore et al.1970; Pollock et al.1969) as an evaluation variable while others (Costill and Winrow, 1970; Fox and Costill, 1972; Saltin and Astrand, 1967) have used it as a means of comparing highly trained athletes.

Hickson et al.(1977) reported an average increase of 16.8 ml/kg/min. (44%) as the result of 10 week training, 6 days per week for 40 minutes per day. The authors suggest from the results that aerobic capacity can increase more rapidly and to a greater extent in response to training than has generally been thought.

For 3 days per week the training programme consisted of six 5 minute long intervals of bicycling against a resistance adjusted so that each subject attained $\dot{V}O_2$max during the 5-minute exercise period. The 5 minute exercise bouts were separated by 2 minute recovery periods during which the subjects pedalled against a resistance requiring 50-60% of their $\dot{V}O_2$max. As the subject's work capacity increased, the exercise rate on the bicycle was increased from week to week as needed to elicit their $\dot{V}O_2$max.

On the alternate 3 days a running program consisted of continuous running as fast as possible, for 30 minutes/day during the first week,

Table 2. Comparison of Maximal Oxygen Uptake Changes with Endurance Training.

Investigator	Date	n	Weeks Training	Days Per Week	VO_2max ml/kg/min. Pre	Post	% improvement
Ekblom	1969	8	16	3	45.1	50.7	12
Saltin	1969	42	8-10	2+	37.5	44.3	14
Wilmore	1970	16	10	3	40.1	44.1	10
Davies	1971	28	27	1-5	50.8	52.5	3
Knuttgen	1973	37	8	3	45.1	54.3	20
Fox	1973	8	7½	5	45.4	49.0	8
Fox	1973	8	7½	5	45.8	48.2	5
Fox	1973	8	7½	5	44.4	48.4	9
Wenger	1975	12	7	3	39.5	53.3	33
Wenger	1975	12	7	3	39.3	48.9	24
Fox	1975	26	7	2	43.5	48.0	10
Fox	1975	23	7	4	44.2	48.7	10
Fox	1975	10	13	2	43.2	49.2	14
Fox	1975	10	13	4	41.9	47.7	14
Eddy	1977	14	7	4	41.6	47.8	15
Fox	1977	30	8	3	52.1	55.3	6
Hickson	1977	8	10	6	38.6	55.4	44

35 minutes/day during the second week, and 40 minutes/day or longer thereafter.

Intensity

Many investigators (Davies et al.1970; Ekblom, 1969; Ekblom et al. 1968; Saltin et al.1968, Girandola and Katch, 1973), have reported that general exercise programmes of running and sports participation will increase endurance capacity, but have neglected to adequately quantity their methods. However, some authors have attempted to control the variables intensity, duration and total work performed in each training session.

Sharkey (1970) randomly assigned 36 college men to the cells of 3x2 factorial design which included three intensities (trained heart rates of 130, 150 and 170 b/min.) and two levels of work (7500 and 15000 kpm of total work). The 6 week training programme was conducted 3 days per week. He concluded that intensity did not significantly influence the extent of training changes when total work was held constant. Also, intensity and duration of training did not interaet to prodce significantly different training changes.

Wenger and Macnab (1975) equated groups on initial fitness levels and varied the relative intensities and duration of work while keeping total work performed equal. The group which trained at 100% of their $\dot{V}O_2$max show significantly greater improvement than a group which trained at 60% of their $\dot{V}O_2$max.

Burke and Franks (1975) trained 16 male students randomly assigned

to 3 training groups (86%, 75% and 65% of HR max), with all groups performing the same total work of 12000 kpm per training session. The results showed that the highest intensity training group improved the most, although there was no significant difference between the 85% and 75% group, the evaluation of training effect being measured as a change in $\dot{V}O_2$max.

Other studies (Fox et al.1977; Eddy et al.1977) have also held total power output constant throughout training sessions.

Heart rate has been used by a few authors as a measure of relative intensity. Sharkey and Holleman (1967) and Sharkey (1970) used training heart rates of 120, 150, 180 and 130, 150 and 170 b/min. respectively and Faria (1970) in a study involving bench stepping used target heart rates of 120-130, 140-150, and 160-170 b/min. as a measure of intensity. Massicotte and Macnab (1974) trained young boys for 6 weeks on bicycle ergometers and used training heart rates of 130-140, 150-160, and 170-180 b/min. to measure intensity.

The use of monitoring heart rate has been used extensively in determining the length of recovery during interval training. The original view of Reindell and Gerschler (Sprecher, 1964) was that the heart rate must return to 120 b/min. before the next work interval should be attempted.

Fox and Mathews (1974) suggest target heart rates during recovery intervals depending on age. For example, for men and women less than 20 years old, the heart rate should drop to at least 150 b/min. between repetitions and 120 b/min. between sets. This method of recovery between sets, being regulated by pulse, was utilized by Petrowskij (1974) in

training of Valeri Borzov and other Soviet sprinters.

Mode of Training

The evolution of training programmes has developed over decades from an intuitive approach to a point at the present time where specific energy systems are developed that are predominantly used during performance of various sports. This transition has taken place through greater understanding concerning the immediate physiological responses in humans to specific performance tasks. Doherty (1971) suggests that there has been a great deal of trial and error experience, and even today it is surprising how many top athletes are not aware of the effects of their training programmes.

Continuous Training

This mode of training takes many forms such as Long Slow Distance (L.S.D.), steady state training or aerobic training. Essentially it is used in the development of oxygen utilization.

One of the most distinguished proponents of this training has been Arthur Lydiard, who maintains that the success of his runners has been due to the aerobic foundations of marathon training.

Wilt (1968) subdivided continuous training into two categories - slow and fast training. Most investigations assess the higher intensity category such as Gollnick et al. (1973) who studied the effects of 5 months endurance training on biochemical variables. The subjects

trained on a bicycle ergometer 1 hour/day, 4 days/week at a power output requiring 75% of their $\dot{V}O_2max$, based on pre-training $\dot{V}O_2max$ values.

Eddy et al.(1977) conducted a continuous training programme where the subjects exercised at 70% $\dot{V}O_2max$, 4 days/week for 7 weeks. An early study where continuous and intermittent running were compared, was done by Christensen et al (1960). In this study the intensity was determined by treadmill speed, (20 km/h) rather than relative intensity.

Wenger and Macnab (1975) trained two groups at 100% and 60% of their $\dot{V}O_2max$ for seven weeks with initial fitness and the total work equated between the groups. The group which trained at 100% $\dot{V}O_2max$ showed significantly greater improvements in $\dot{V}O_2max$. The authors concluded that the magnitude of the relative intensity of the training stimulus is critical in achieving optimal increases in maximum oxygen consumption when the total work and initial fitness level of the subjects are equated.

Interval Training

Before discussing the development of interval training as a systematic method of conditioning, the following is a summary of its components. Interval training is a series of repeated bouts of exercise alternated with periods of relief (Mathews and Fox, 1976). The objective is the development of speed and endurance, the degree to which each is stressed being dependent on the intensity of effort.

An interval training programme may be developed through the mani-

pulation of several variables.

1. Distance of the work interval.
2. Rate of the work interval.
3. Time of recovery interval.
4. Type of activity during recovery.
5. Number of repetitions.

Other terms associated with interval training include:

Sets: A series of work and recvoery intervals.

Repetitions: The number of work intervals within one set.

Training Distance: The distance in the work interval.

Training Time: The rate at which the work is to be accomplished in the work interval.

Interval training is one of the most universally employed methods of training in the preparation of most sports. It developed from Fartlek training, in English meaning 'speed-play', which is a system of endurance training which alternates strenuous and easy running over varied terrain.

The pioneer of the fast-slow approach to training was a Finnish coach, Lauri Pikhala, who, at about the end of the First World War, stressed the rhythm between work and rest in a method he called Tarrace Training (Smit, 1964). This form of training was first exploited by the runner Paovo Nurmi during the twenties. In the 1930's, Nurmi's training methods were adopted by Gosta Holmer, the Swedish national

coach, and as a result, a form of fast-slow running, known as Fartlek evolved (Down, 1964).

These methods were experimented with by other coaches including Hungarian Mihaly Igloi and in Germany by Woldemar Gerschler. In the pre-Second World War period, Gerschler, guided by physiologist Dr. Herbert Reindell, experimented with the Fartlek system and using a guinea-pig, international 400m runner Rudolf Harbig, introduced more speed into the training programme without reducing endurance. Harbig proceded to break world records but the War cut short his success.

The German ideas disappeared until the emergence of Emil Zatopek, who applied the concept of "ausdauer" (Interval Training) to long distance.

Interval training, as organized by Reindell, Roskamm and Gerschler (1962) is centred on the development of the heart. They contend that the work interval provides the developmental challenge while the recovery provides the response (Doherty, 1971) resulting in what Gerschler terms, strengthening of the heart. The basic format of their training is fairly strict and can be summarized as follows:

1. Bring the heart to 120 b/min. by a preliminary warm up.

2. From this point, the runner does a given distance - 100, 150, or 200m. in a given time which will bring the heart to about 170-180 b/min.

3. In recovery the heart should take a maximum of 90 secs. to return to 120 b/min. This time could be shortened however but it is important that the heart rate returns to 120-125 b/min. (Sprecher, 1964).

Perhaps the most significant comment concern interval training is that it is the coaches task to "discover" the correct mixture or combination of interval training variables for every individual (Nett, 1956). Smit (1964) comments that, in other words, up to that time (1956) it was obviously largely a matter of trial and error.

The physiological effects of endurance training carried out through interval or intermittent training have slowly come under scrutiny by exercise physiologists. Work by Christensen (1956), Christensen et al. (1960) and Astrand et al. (1960) approached the problem of optimal stimulus for endurance development through oxygen consumption values and lactic acid rather than the effects on the heart as by Reindell and Gerschler. The Scandinavian results suggested that the total amount of work may be divided into suitable periods in such a way that one can induce training of large muscle groups without simultaneously loading the respiratory and circulatory systems (work with short periods over a long time). With longer exercise periods, 2 or 3 minutes, a training effect can also be induced on respiration and circulation.

Karlsson et al. (1967) exercised six subjects on a treadmill (3^{o} slope); two trained and two untrained males and one trained and one untrained female. The authors concluded that for optimal training of the circulation the load on the oxygen transport system should probably be maximal. But since maximal oxygen uptake can be reached at submaximal speed, lower speeds may be sufficient and perhaps optimal as a training stimulus.

Knuttgen et al. (1973) conditioned Swedish military conscripts in three separate interval training programmes. Group I (N=20): 15 seconds exercise + 15 seconds rest, 3 days/week for 2 months. Group II (N=9): 3

minutes exercise + 3 minutes rest, 3 days/week for 2 months. Group III (N=8) 1 month no formal programme, then 3 minutes exercise + 3 minutes rest, 5 days/week for 1 month. Amongst the conclusions from this study were that: (1) marked improvement in aerobic power can be brought about in a short period of time, (2) the training based on 3 minute periods was more effective than 15 second periods.

Fox et al.(1977) conditioned 30 untrained students in order to examine the effects of low power and high power interval training, low power (LP) consisting of 7 reps. of 120 second runs and high power (HP) consisting of 19 reps. of 30 second runs. Recovery intervals were such that the heart returned to between 140-120 b/min. and the programme was conducted for 8 weeks, 3 days/week. The findings of this study showed significant but equal increases in max $\dot{V}O_2$ in both groups, but although both groups exhibited significantly lower lactate levels at the same absolute power output, the greatest decrease was in the low power group.

Studies Comparing Continuous versus Interval Training

Saltin et al.(1976) reviews the terminology and physiological differences between continuous and discontinuous work. The authors characterize continuous exercise as a product of intensity and duration, and suggest that heart rate may be used as a index of the relative work intensity. Discontinuous work on the other hand is more complex, the intensity of the external work being defined as average power output (APO).

Several investigators (Roskamm, 1967; Fox et al.1973; Fox et al. 1969) strongly imply that interval training, results in the best possible improvement in endurance, whereas the practical applicators of training, the athletes, (long distance runners, orienteers, cross-country skiers and bicyclists) have usually used continuous training methods to develop high aerobic capacities (Saltin et al. 1976).

Several studies have examined both modes of training within the same study. Roskamm (1967) equated groups on total work performed, 20 subjects being in each group. Group I trained continuous at a relative power output which was equal to a heart rate at rest plus 70% of the difference between heart rate at rest and during maximum work on the ergometer. Group II carried out interval training, with the power output being changed every minute. For one minute the load was 50% higher than it would have been in Group I with continuous training, and in the next minute, it was 50% lower. Group III trained as Group II except that the duration of each power output was 2½ minutes instead of 1 minute. Group IV was a control group. The findings were that high intensity, interval type work produced better improvement than low intensity continuous work.

Eddy (1977) examined the effects of continuous and interval training in men and women with the total daily work output being equated. The continuous group trained for 7 weeks, 4 days per week at 70% $\dot{V}O_2$max. The Interval group trained at 100% $\dot{V}O_2$max with rest to work ratio of 1 minute work: 1 minute rest. The duration of each training session was assigned so that each subject would complete 10,000 kpm of work per

session during the first week. Each subsequent week the load was increased 3000 kpm. Eddy found that both groups increased significantly ($p < 0.005$), the improvement being approximately equal, 15.2% and 14.3% increase for the continuous group and interval group respectively, suggesting no differences between methods. Both methods also produced almost idential changes in heart rate response and blood lactic acid concentration at submaximal power outputs.

Mechanical Efficiency

In studies by Christensen et al.(1960) and Astrand et al.(1960) the efficiency of interval and continuous exercise were compared, the tendency being for a slightly lower efficiency with interval work was seen.

Ekbolm et al.(1971) reported slightly lower work efficiency in interval exercise. In this study interval work consisted of 30 seconds work at 2190 kpm plus 30 seconds rest, and in continuous work, the power output was 1170 kpm/min. The average efficiencies were 21.5% for intermittent and 24% for continuous work. Astrand et al.(1960) reported values of 21.7% and 23.4% respectively.

Edwards et al.(1973) found significantly lower values for mechanical efficiency in interval exercise than at the same average power output performed continuously. Edwards however used continuous power outputs of 375 kpm/min and 890 kpm/min resulting in mechanical efficiencies of 31.1% and 27.2% respectively. The efficiency for the corresponding interval power outputs were only 23.0% and 22.6%. A possible explanation suggested by Edwards was that in Christensen's experiments with inter-

mittent exercise, a complete rest was used, whereas their recovery periods consisted of no-load exercise. Saltin et al.(1976) report unpublished data by Pedersen suggesting almost idential mechanical efficiencies in continuous and interval exercise. As possible explanation for the differences, Saltin et al.(1976) suggest that different models for interval exercise may alter the proportions of lactate removal that which is oxidised or which is used as a precursor in gluconeogenesis.

After considering this review of literature it is evident that there has been no organized investigation into the quantification of training, in terms of critical criteria of relative intensity or modes of training, particularly with reference to interval training. As a result of previous pilot work, it is hoped that this research will allow for a more meaningful approach to training.

APPENDIX B

APPENDIX B

SUMMARY OF $\dot{V}O_2max$ VALUES AT PRE, MID AND POST TEST TIMES

	140 b/min. and 160 b/min.			172 b/min. and 160 b/min.		
	Pre	Mid	Post	Pre	Mid	Post
CONTINUOUS TRAINING	55.48	53.97	52.00	54.83	57.47	57.41
	55.07	55.25	52.07	51.34	54.25	55.19
	51.50	52.52	52.39	51.35	59.54	51.08
	47.37	47.07	48.88	48.08	59.69	58.33
	50.76	50.18	48.77	45.94	58.40	50.72
	48.63	52.78	52.30	45.03	51.89	57.10

	140 b/min. and 160 b/min.			172+b/min. and 160 b/min.		
	Pre	Mid	Post	Pre	Mid	Post
INTERVAL TRAINING	51.59	52.48	53.83	52.95	54.63	51.16
	55.05	55.73	52.68	51.51	51.17	48.53
	51.23	52.34	51.40	58.51	60.30	55.24
	45.52	45.66	47.43	48.18	48.95	46.74
	45.70	48.06	49.64	45.62	46.70	51.19
	44.34	45.16	48.05	48.18	51.95	49.43

APPENDIX C

APPENDIX C

EXAMPLES OF CHANGES IN AVERAGE Kp. LOAD TO ELICIT A RELATIVE INTENSITY HEART RATE OF 172 b/min. DURING CONTINUOUS TRAINING

Training Day	SUBJECT A	SUBJECT B
1	2.62	3.01
2	2.97	3.15
3	3.22	3.19
4	3.26	3.32
5	3.37	3.21
6	3.51	3.50
7	3.62	3.60
8	3.83	3.94
9	3.89	4.08
10	3.93	3.97

APPENDIX D

SUMMARY OF THREE-WAY ANALYSIS OF VARIANCE

VARIABLE	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
MODE OF TRAINING	A	84.44	1	84.44	2.97	0.100
RELATIVE INTENSITY	B	59.37	1	59.37	2.09	0.164
	AB	3.19	1	3.19	0.11	0.741
TEST TIME	C	83.06	2	41.53	8.57	0.008
	AC	24.12	2	12.06	2.49	0.096
	BC	41.19	2	20.59	4.25	0.021
	ABC	54.81	2	27.41	5.66	0.007
	S-within	193.75	40	4.84		

NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR $\dot{V}O_2max$ AT PRE, MID AND POST TEST TIMES

		Pre	Post	Mid
	MEANS	50.2	51.7	52.8
Pre	50.2	-	*	**
Post	51.7		-	-
Mid	52.8			-
	R =		2	3

The multiplier is 0.45.

* $p < 0.05$ ** $p < 0.01$ - NS

NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR $\dot{V}O_2$max OF 140 AND 160 B/min., AND 172 and 160 b/min. RELATIVE INTENSITIES AT PRE, MID AND POST TEST TIMES.

		172 Pre	140 Pre	160 Post	172 Mid	160 Post	172 Mid
	MEANS	50.1	50.2	50.8	50.9	52.7	54.6
172 Pre	50.1	-	-	-	-	*	**
140 Pre	50.2		-	-	-	-	**
160 Post	50.8			-	-	-	**
172 Mid	50.9				-	-	**
160 Post	52.7					-	-
172 Post	54.6						-
	R =		2	3	4	5	6

The multiplier is 0.635 * $p < 0.05$ ** $p < 0.01$

- NS

NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR $\dot{V}O_2max$ OF CONTINUOUS AND INTERVAL TRAINING GROUPS AT PRE, MID, AND POST TEST TIMES

		I Pre	I Post	C Pre	I Mid	C Post	C Mid
	MEANS	49.9	50.4	50.4	51.1	53.0	54.4
I Pre	49.9	-	-	-	-	**	**
I Post	50.4		-	-	-	*	**
C Pre	50.4			-	-	-	**
I Mid	51.1				-	-	**
C Post	53.0					-	-
C Mid	54.4						-
	R =		2	3	4	5	6

The multiplier is 0.635 * $p < 0.05$ ** $p < 0.01$ - NS

Summary of Analyses of Simple Interactions

Source	Calculation	SS	df	MS	F
A x C at b_1	92393.6 - 92383.3 - 92359.0 + 92355.2	6.52	2	3.26	0.67
A x C at b_2	99354.4 - 99221.5 - 99159.9 + 99099.0	72.0	2	36	7.44**
S/ABC			40	4.84	

** $p < 0.01$

Source	Calculation	SS	df	MS	F
B x C at a_1	100022.6 - 99837.7 - 99891.7 + 99792.8	86.0	2	43	8.88**
B x C at a_2	91725.4 - 91705.5 - 91697.2 + 91687.8	10.46	2	5.23	1.08
S/ABC			40	4.84	

** $p < 0.01$

Selected Mean Comparisons

Group	Mean ($\dot{V}O_2$ max)
C172 Pre	49.4
C172 Mid	56.9
C172 Post	55.0
I172 Pre	50.8
I172 Mid	52.3
I172 Post	50.4
C140 Pre	51.5
C140 Mid	52.0
C140 Post	51.1

Hypothesis	F
H_1 : C172 Pre = C140 Pre	2.73
H_2 : C172 Mid > C140 Mid	14.89**
H_3 : C172 Post > C140 Post	9.42**
H_4 : C172 Pre = I172 Pre	1.21
H_5 : C172 Mid > I172 Mid	13.12**
H_6 : C172 Post > I172 Post	13.12**

$F(1,40)_{0.01} = 7.31$

APPENDIX E

APPENDIX E

SUMMARY OF DURATION (MIN.) OF TRAINING FOR EACH TRAINING SECTION

	140 b/min.	160 b/min.	172 b/min.	160 b/min.
CONTINUOUS TRAINING	19.00	14.20	16.72	18.20
	14.75	11.95	14.00	13.90
	23.55	18.85	17.65	19.95
	18.42	14.92	13.77	16.50
	17.25	12.50	13.10	14.25
	13.00	9.42	12.35	15.30

	140 b/min.	160 b/min.	172+ b/min.	160 b/min.
INTERVAL TRAINING	19.52	17.03	17.33	18.88
	22.99	18.00	15.79	18.06
	20.04	16.17	20.99	17.17
	20.31	15.46	14.36	14.76
	23.38	17.03	14.82	16.32
	21.39	14.85	16.52	15.44